

# QUANTITATIVE USE OF LAGRANGIAN DATA IN NUMERICAL MODELS

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## LONG-TERM GOALS

This research focuses on quantifying the important dynamical mechanisms which govern the evolution of submesoscale processes and their interactions with small and mesoscale motions. Two long-term products of this research will be dynamically consistent methods of parameterizing the submesoscale processes for regional scale models and inferring subsurface conditions from high resolution surface observations.

## OBJECTIVES

The research has two components with specific objectives for each.

*Blending high resolution disparate data and numerical models* - There are two principal objectives of this component of the research. The first is to develop dynamically consistent methods to utilize the information in such diverse data sets as HF radar, Lagrangian observations, passive remote sensing and ADCP data with model results to provide nowcasts in support of Rapid Environmental Assessment (REA). The other is to develop feature models that will allow us to use high resolution surface data to infer subsurface conditions.

*Particle-in-cell (PIC) ocean model.* The principal objective of this component of the research is to develop a PIC model for two (or more) active layers which is capable of resolving the location and evolution of fronts in coastal and estuarine regimes. This methodology requires massively parallel processor (MPP) architectures to be fully effective.

## APPROACH

*Blending high resolution disparate data and numerical models* - The approach is based on a unique special spectral decomposition in which the data are projected onto numerically generated basis functions. The method was described by Ereemeev *et al.* (1992a), and applied to a variety of oceanographic data by Ereemeev *et al.* (1992b), Ereemeev *et al.* (1995a,b) and Lipphardt *et al.* (1997). This approach was selected because it has a number of attributes appropriate for REA. It is spectral and thus applicable to disparate data; it is readily adapted to arbitrarily shaped domains and

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thus is ideal for REA scenarios; the spatial basis set can be calculated to arbitrary accuracy independent of the data which is appealing for high resolution data; boundary information from numerical models is easily incorporated with observations which simplifies blending of observations and model information; and the rendered velocity field is three-dimensionally incompressible.

*PIC ocean model* - This approach, originally pioneered by Pavia and Cushman-Roisin (1988), solves the Euler equations by a hybrid approach. The acceleration terms are solved at particles while the gradient terms are solved on a grid. This method was selected because it is capable of faithfully resolving fronts while retaining primitive equation dynamics.

## WORK COMPLETED

*Blending high resolution disparate data and numerical models* - During the past year a substantial number of research milestones were achieved. Code has been completed and tested which allows us to calculate the spatial basis functions for any geometry. Very recently we have made further improvements in the numerics by utilizing sparse matrix methods. This reduces the run time from hours to minutes in a workstation environment. For proof of concept we applied the methodology to HF radar data from Monterey Bay obtained by Jeff Paduan, and Lagrangian data from the Latex shelf area in the Gulf of Mexico. The results are very encouraging. In March we assisted in organizing the SACLANT/ODU/ONR conference on Rapid Environmental Assessment in Lercici Italy. In July we hosted an informal workshop on the scientific and technical issues related to analyzing HF radar data and blending it with numerical models. This fall we are collaborating with other ONR sponsored scientists who are comparing different HF radar measurements in Chesapeake Bay.

*PIC ocean model* - During the past year we were able to get the first ever multilayered PIC model to run on the MPP at Hawaii. The problem considered was a shallow lens over a deep layer which outcrops around the lens. A number of scenarios were studied. Agreement with benchmark cases was excellent. As hoped the method demonstrated ability to track the evolution of the front associated with the surface outcropping of the lower layer.

## RESULTS

*Blending high resolution disparate data and numerical models* - We are well into the analysis of both HF radar data from Monterey Bay and Lagrangian data from the Gulf of Mexico. In Monterey Bay our method provides a natural way of filtering surface divergence modes from the data so that velocities from the radar data can be assimilated in a numerical model. We have been studying the time series of the spectral amplitudes for the surface velocity and have identified a number of modes associated with tides and meteorological events. For the Gulf of Mexico we were able to use the method to prepare maps for the entire shelf area from just drifter data and basin scale model information. Results of this work are described in Lipphardt *et al.* (1997).

*PIC ocean model* - A detailed description of the method along with results of experiments with the reduced gravity and 1.5 layer versions has been accepted for publication. Mr. J. Holdzkom is documentating the fully interactive two layer model in his dissertation.

## **IMPACT/APPLICATIONS**

*Blending high resolution disparate data and ocean models* - The approach we have developed for blending high resolution disparate data with model information addresses a number of deficiencies in present approaches to this problem which limit their applicability to REA scenarios. It is applicable to any data and any grid at any resolution, and it incorporates traditional boundary conditions which simplify the problem of blending data and model information. Finally through the use of sparse matrix methods the whole procedure can be executed quickly in a workstation environment.

*PIC ocean model* - This work has achieved the original goal of developing a PIC model for multilayer systems. The success of this approach is directly attributable to the development of massively parallel computer architectures. The evolution of massively parallel architectures made this approach feasible for Naval applications. We anticipate this model can be embedded in a regional scale model to provide high resolution forecasts of frontal features. It could also be used for processing high resolution remote sensing data for blending and assimilation into the regional models.

## **TRANSITIONS**

Recently we started working with the Naval Research Lab's Ocean Dynamics and Prediction Branch (Stennis Space Center - NRLSSC) in blending high resolution disparate data with ocean models. The test bed for this effort is the Latex shelf area in the Gulf of Mexico, where a substantial amount of high resolution drifter data along with hydrographic moored data is available. The NRLSSC 1/16 degree model of the Gulf of Mexico is being made available for this study. This work will constitute the dissertation of LCDR W. Schulz. We expect it will take two years to complete.

## **RELATED PROJECTS**

We recently completed an assessment for an Ocean General Circulation Model for the Japanese agency JAMSTEC. The essential finding was that this state of the art model did not parameterize enough of the mixed layer boundary physics to account for modern observations from drifters and ADCP data suites.

As part of our ONR sponsored work we are starting collaborations with scientists from the Naval Post Graduate School, Hydroqual Inc., University of Southern Mississippi and Ocean Physics Research and Development to continue analysis of HF radar data and to assimilate this data into predictive models.

We have also started collaborations with L. Kantha at the University of Colorado to use our methodology to study the long term scales of motion in the Gulf of Mexico.

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